LTE from an LMR View and FirstNet

Seattle Communications Academy

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Presentation Overview

1. Background…why the discussion?
2. FirstNet overview
3. Comparison of LTE & LMR
4. Implications for Public Safety Communicati
5. The Future

1. Background – why the discussion?

Cellular 4G LTE technology implementation including AT&T FirstNet™, has dominated technology discussion in the LMR world recently.

LTE technology will impact wireless voice & data communications for both LMR and commercial users

The cellular world, its history, and technologies have some similarities with LMR, but many differences. For most people, there’s a big knowledge gap.

This is a brief, non-technical overview of some key aspects LTE technology and FirstNet from a radio perspective, to broaden your understanding of this future force in wireless

1. Background – why the discussion?

FirstNet™ awarded AT&T contract to build & operate the Band 14* Nationwide Public-Safety Broadband Network (NPSBN)

Deployment scheduled over the next 3-4 years, effectively a permanent, strategic, voice & data communications solution for the future

All government entities eligible for “special access and privileges” to AT&T’s wireless network via FirstNet™

So, who asked for this….? First Responders. Now they’ve got it.

Key Points
AT&T only bidder
$46.5B Private Public Partnership
25 year contract
Funded through an FCC spectrum auction

1. Background – why the discussion?

AT&T's existing Network will be modified, nationwide

- the AT&T Radio Access Network (RAN) already operates on *up to* 5 bands nationally
- all sites will have Band 14* capability added
- additional sites built to extend coverage or capacity
- special provisioning of network for QoS and other feature for FirstNet users
- dedicated VPN and backhaul partitions PS from general users
- end to end encryption
- sites "hardened" (reliance & reliability) with generators, extra battery backup, etc.
- upgrades will allow meeting of an aggressive Service Level Agreement (SLA) requirement
- new sites built to extended coverage into regions previously not considered profitable on ROI
- massive workforce mobilization to complete *in ≤5 years*

Washington (Governor) Opted In for FirstNet

- OneNet is the FirstNet™ PS Wireless Technology Program for WA
- Washington State will likely see over 50 new AT&T sites constructed*
- FirstNet will evolve with technology as 3GPP standards evolve to 5G

https://www.firstnet.gov
https://onenet.wa.gov

2. Comparison Between LTE & LMR

Where did LTE come from?

Third Generation Partnership Project

- 3GPP Formed in 1998
- Generally similar in role to TIA-102/TR-8 for APCO P25, it's their Standards Body for the Cellular Wireless Technology
    - formed by ETSI, ARIB, TTC, CCSA, ATIS
    - consists of several Technical Specifications Groups (TSGs)
- Internationally minded with local and regional requirements in mind
    - work in 3GPP is carried out with ITU recommendations in mind
  - work results submitted to ITU

Truly Open Standards

- can use multi-vendor equipment interconnections/configurations
- This really means multi-vendor in the truest sense
- different when compared to TIA-102, (ex. ISSI, CSSI, etc.)
- different when compared to vendor specific implementations in LMR

2. Comparison Between LTE & LMR

Technology Standards Progression – LTE & 3GPP

Cellular and LMR have similar development history

Evolution process took both industries year to converge

Both driven by technology, spectrum, mark demands

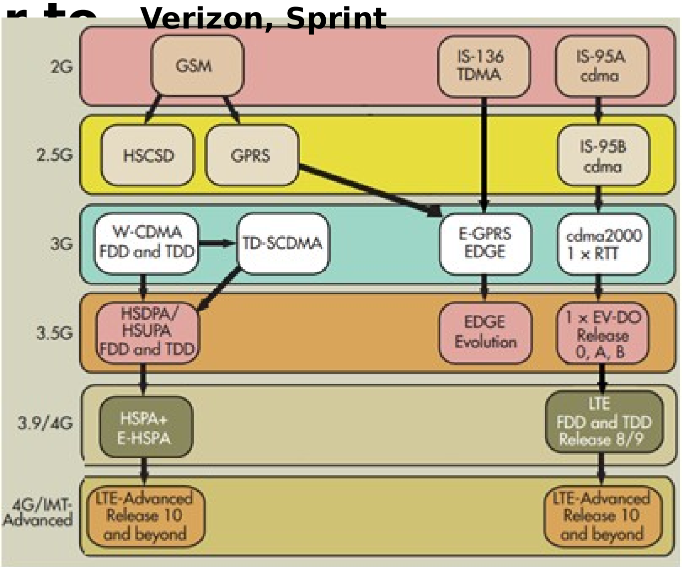
LMR (TIA-EIA/ETSI)
- LTR/ESAS®/PassPort®
- MPT1327/TETRA
- iDEN
- DMR/DPMR/NXDN
- EDACS/SmartNet
- TETRAPOL
- TETRA
- APCO P25 I/II*
- ???

Amateur
AM/SSB
- D-Star/DMR/C4FM Fusion
- CW/RTTY/AMTOR
- Packet/Pactor I/II/III/IV
- BPSK/QPSK31/63
- SSTV/Hellschreiber
- JT6M/JT65/MT63
- Olivia/Throb/Contestia

....and the beat goes on...

Cellular(3GPP)
- AMPS
- TDMA
- GSM
- CDMA
- UMTS/EV-DO
- WiMax
- LTE**
- LTE A/Pro**
- 5G**

AT&T, T-Mobile
Verizon, Sprint



***as of 2019, there are no current plans for further significant P25 evolution or enhancement (i.e., Phase III) from TIA-102/TR-8**

**** all are based upon (standardized) 3GPP LTE, just enhancements in modulation and BW for data performance & features**

Wireless Evolution… "natural selection ?

Technology Incompatibility
Market fragmentation
Products based on carrier partnerships
Band Specific
Limited product=Higher costs

Convergence

Technology Compatibility
Harmonized & Evolving Standard
Common RF chipsets & CODECS
Band agnostic
Mass production=Lower

2. Comparison Between LMR & LTE

System Level Comparison

P25 TDMA Trunked Radio System

- mission critical voice
- typically supports a single technology
- interoperability with other systems
- supports multiple bands
- design performance static
- single control channel per site/system
- asymmetric modulation (DL vs. UL)
- single order modulation
- multicast and/or simulcast
- receiver voting
- limited Rx diversity

RAN (Radio Access Network)

- dynamically optimized data & voice session
- supports 4G and backward compatible with 3G
- interoperability w/ national and intl. carriers
- supports multiple bands simultaneously
- design performance dynamic
- multiple control & sync channels
- asymmetric modulation (DL vs. UL)
- multi-order modulation
- always simulcast
- Rx and Tx diversity, polarization diversity +/- 45
- MIMO (4x2, 4x

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2. Comparison between LTE and LMR

Design Comparison

(We go high, they go low)

LMR is primarily wide-area *coverage* based

- altitude is range, high sites preferred (except urban)
- omnidirectional (non-sectored) coverage
- site spacing 5 ~ 15 miles (typical, V/U/800)
- limited use of antenna down-tilt
- directed power control of subscriber radio unused
- subscriber radio determines best trunked site
- no *system directed* handoff to optimal site

LTE RAN is primarily *capacity* based coverage

- altitude gives interference, low sites optimal
- sectored coverage (3-sector)
- site spacing < 1mi. to < a few miles
- down-tilt heavily used
- UE power control* always used (open/closed loop)
- UE and RAN orchestrate site selection* together
- RAN directed handoff* to optimal site, as needed

Key Point: continuous collaboration between RAN and UE for signal quality control during session (every 1 msec. !)

2. Comparison between LTE and LMR

Power & Survivability Comparison

(along with site security, this is a very contentious subject…)

LMR trunked public safety sites

- battery banks
- usually 25-50 kW site gensets
- several days to weeks of run time
- usually part of original design

LTE “Macro” sites

- battery banks
- some sites have gensets, or will be upgraded
- contracted for fuel replenishment
- no standard for minimum run times
- emergency power retrofits can be challenging
  (permitting, pad size limits)
- limitations for backup power in many urban sites
  (weight loading on rooftops, hazardous fuels, etc.)

Reality: during a real major event (ex. Cascadia rising), power & survivability for both PS LMR and carrier LTE networks will be challenged:

- *commercial power grid time-to-repair vs. site standby power run times*
- *accessibility via congested, blocked, or closed roadways*
- *local fuel reserves or rationing of fuel (diesel, LPG)*

2. Comparison between LTE and LMR

Power & Survivability Comparison

(along with site security, this is a very contentious subject…)

2. Comparison between LTE & LMR

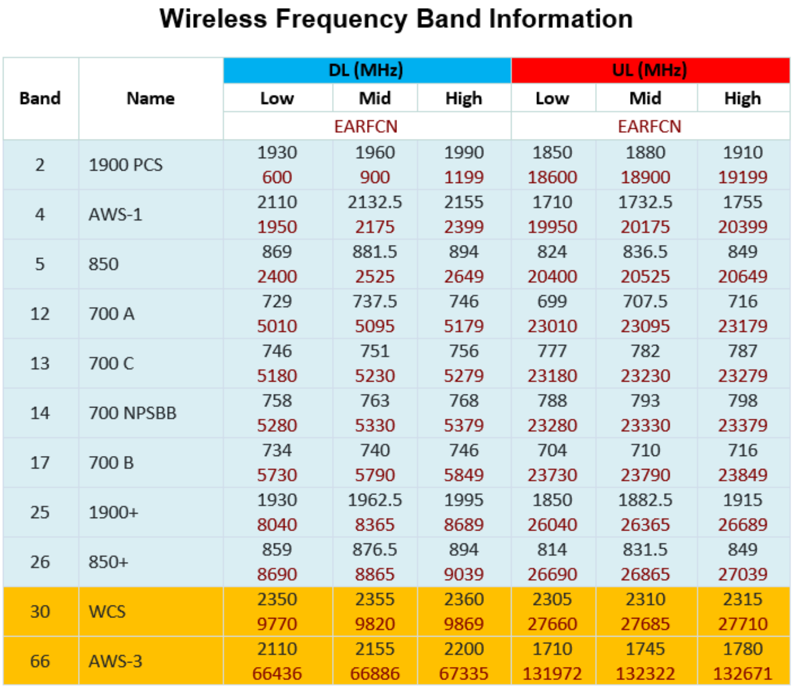
Frequency Spectrum

- Amateur Radio (FCC Part 97) and LMR (FCC Part 90) have a history of being lockstep across some bands (ex. VHF Low/High & UHF)

- Channel depletion & technology migrated PS to 800 & 700 MHz (PS had reserved spectrum). Carriers were already there…started on 800 MHz, but added bands to accommodate capacity and technology

- Currently there are seven (7) carrier bands (600/700/850/1900/2100/2300/2500 MHz), with 5G and new CBRS band that adds 3.5 GHz.

- Cellular Bands referred to by “Band Class #” and Service nomenclature. Channels are designated by their **EARFCN** (Evolved Absolute Radio Frequency Channel Number) see below:



Wireless Frequency Band Information

Band	Name	DL (MHz)			UL (MHz)		
		Low	Mid	High	Low	Mid	High
		EARFCN			EARFCN		
2	1900 PCS	1930 600	1960 900	1990 1199	1850 18600	1880 18900	1910 19199
4	AWS-1	2110 1950	2132.5 2175	2155 2399	1710 19950	1732.5 20175	1755 20399
5	850	869 2400	881.5 2525	894 2649	824 20400	836.5 20525	849 20649
12	700 A	729 5010	737.5 5095	746 5179	699 23010	707.5 23095	716 23179
13	700 C	746 5180	751 5230	756 5279	777 23180	782 23230	787 23279
14	700 NPSBB	758 5280	763 5330	768 5379	788 23280	793 23330	798 23379
17	700 B	734 5730	740 5790	746 5849	704 23730	710 23790	716 23849
25	1900+	1930 8040	1962.5 8365	1995 8689	1850 26040	1882.5 26365	1915 26689
26	850+	859 8690	876.5 8865	894 9039	814 26690	831.5 26865	849 27039
30	WCS	2350 9770	2355 9820	2360 9869	2305 27660	2310 27685	2315 27710
66	AWS-3	2110 66436	2155 66886	2200 67335	1710 131972	1745 132322	1780 132671

BC versus Channel BW Comparison-

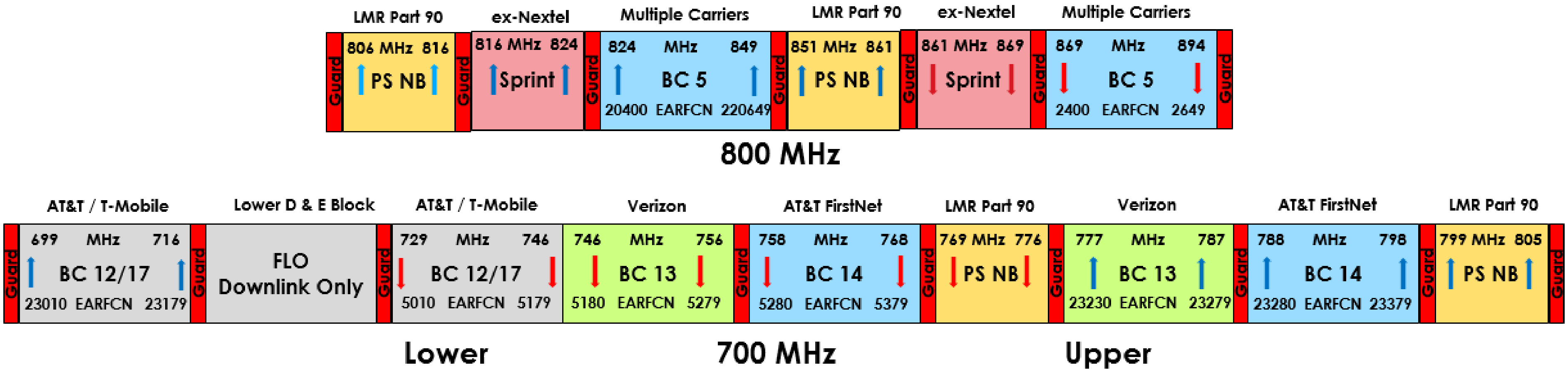
Band Class	**Total BW**
BC 41 (600 T-Mobile)	35 MHz*
BC 12 (700 L)	17 MHz**
BC 13 (700 U)	10 MHz
BC 17 (700 L)	12 MHz
BC 14 (FirstNet)	10 MHz
BC5 (850)	25 MHz**
BC2 (1900PCS)	60 MHz**
BC4 (2100AWS)	45 MHz
BC30 (2300 WCS)	10 MHz
BC41 (Sprint TDD)	194 MHz (2496-2690 MHz)

*in areas with vacated UHF TV Spectrum
** shared blocks

3. Comparison between LTE and LMR

Lets Talk Spectrum – FirstNet Band 14 and the 700/800 MHz Band Plan

- All UE (wireless devices) undergo a registration procedure upon power-on
- Different bands offer different channel sizes, wider BW = better data speeds and capacity
- Lower bands = FSPL> *better range, better building penetration*, *less capacity*
- Higher bands = FSPL<*less range, less building penetration*, *more capacity*
- Different carriers may “home” your device on a particular band class by default
- ***Carrier aggregation*** combined bands together larger, data “pipe” (licensed or unlicensed spectrum)



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Commentary
800 MHz channel pairing (UL/DL offset) @ 45 MHz
700 MHz channel pairing (UL/DL offset) @ 30 MHz
UL & DL not all harmonized (just like Amateur)

↑ UL (input to user device to RAN)

↓ DL (output from RAN to user device)

2. Comparisons between LTE & LMR

What band is my device currently operating on…?

The answer is "you'll likely never know and you shouldn't really care, your device and the network are doing what's best for you".

There are variables that determine your band(s) of operation, most of which your may not be aware of:

Your carrier - spectrum licensed to the 'big 4' differ, with some being unique to a particular carrier.

Your device - newer devices support more bands, especially with carrier aggregation.

Your zip code – carriers divide the country into market regions, which determines available bands.

Your location – frequency band and capacity management by a carrier is affected by being outdoors (served by a macro site) or indoors (served by a DAS).

Your session – bandwidth demands of your session (voice, text, file transfer, video streaming, etc.) will determine the assigned band. Different band classes have different channel sizes.

Your signal quality – the DL RS is constantly being evaluated by your device (and reported back to the RAN) they work together and will hand-off to another band when necessary.

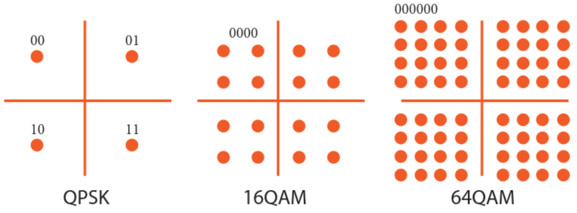
Your SIM – are you special ? Subscriber Profile ID (SPID) FirstNet subscribers devices may initially attempt to "home" on to 700 MHz BC 14 first, or based upon the local policies. They also have priority & preemption on all bands.

Your competing neighbors – a heavily loaded sector approaching max capacity may offload users to other bands if needed.

3. Comparison between LTE and LMR

Overview of LTE Common Air Interface (CAI)

Modulation - Three (3) types of Modulation can be used fc



QPSK = 2 bits per symbol
16QAM = 4 bits per symbol (16=2^4)
64 QAM = 6 bits per symbol (64=2^6)
256 QAM = 8 bits per symbol (256=2^8) *LTE-A/5G

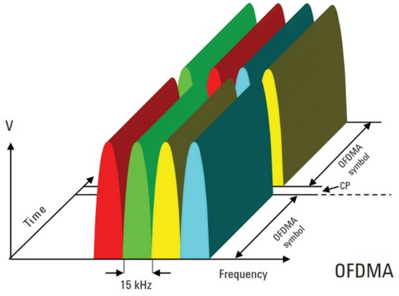
- Modulation/coding rate is actively selected based upon channel conditions/quality reported by user equipment (UE)

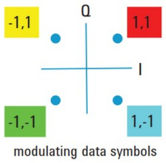
QAM (Quadrature Amplitude Modulation) (*heavily used in CATV, DBS, and WiFi)*

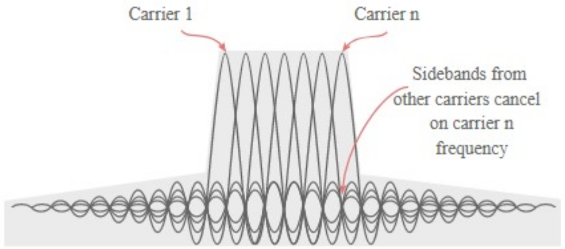
- Use 2 carriers on same frequency with 90° phase shift
- Modulated by I/Q data
- Used because it offers a better level of spectral efficiency.

Channel Access - OFDM (Orthogonal Frequency Division Multiplexing)

- multicarrier modulation splits channel BW into many closely-spaced subcarriers spaced @ 15 kHz
- orthogonality means interference in nulled, no need for individual narrow filters, and now guard bar
- re   er-symbol interference, spectrally efficient
- se   pler shift, generates high P/A







3. Comparison between LTE and LMR

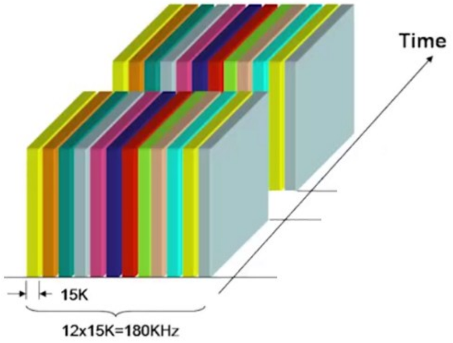
Overview of LTE Common Air Interface (CAI)

Channel Sizes

- standard channel bandwidths defined
- 1.4, 3, 5, 10, 15, 20 MHz
- higher the frequency band (typically) the larger the LTE channel (also depends upon the carrier)
- carrier aggregation allows bundling channels across bands

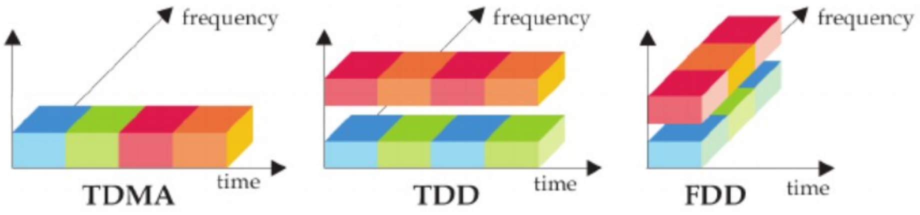
Resource Blocks

- LTE channel divided into multiple “Resource Blocks or RB”
- RB is 180 kHz wide with 12 x 15 kHz subcarriers (12x15kHz=180k
- the LTE channel BW determines how many RBs there can be
- user session determines how many available RBs used (network a

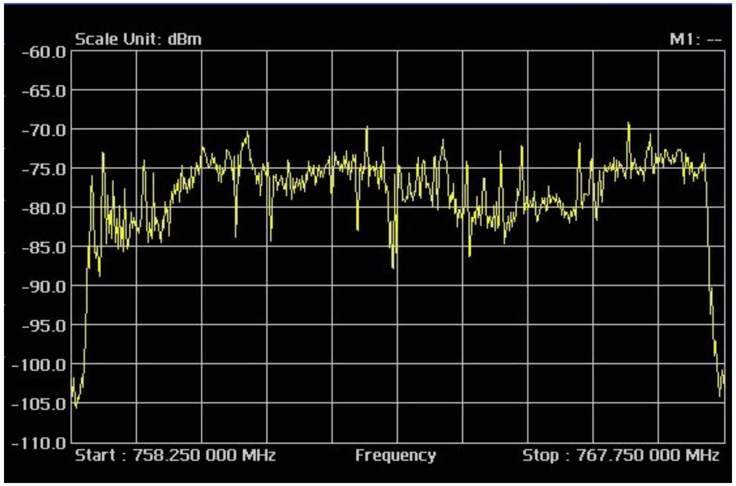


Duplex Channels

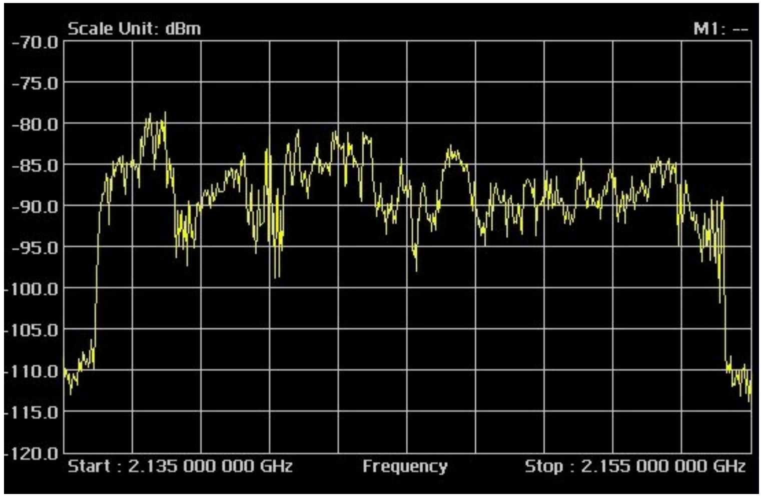
- Frequency Division Duplex (FDD) & Time Division Duplex (TDD)



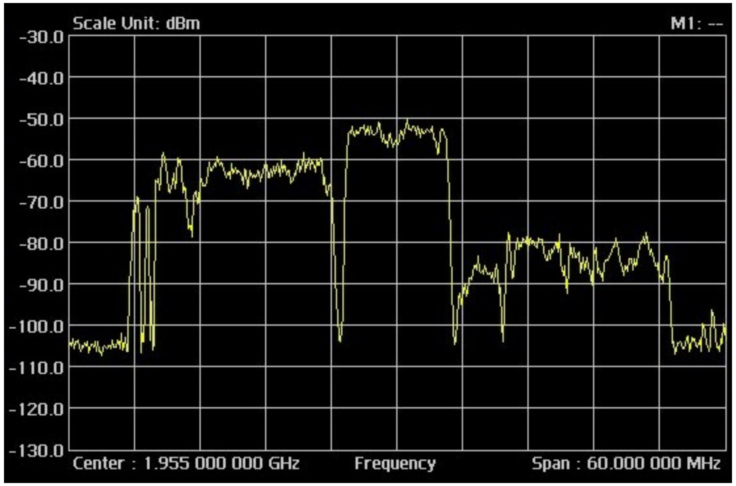
Examples of Off-Air LTE Waveforms (DL)



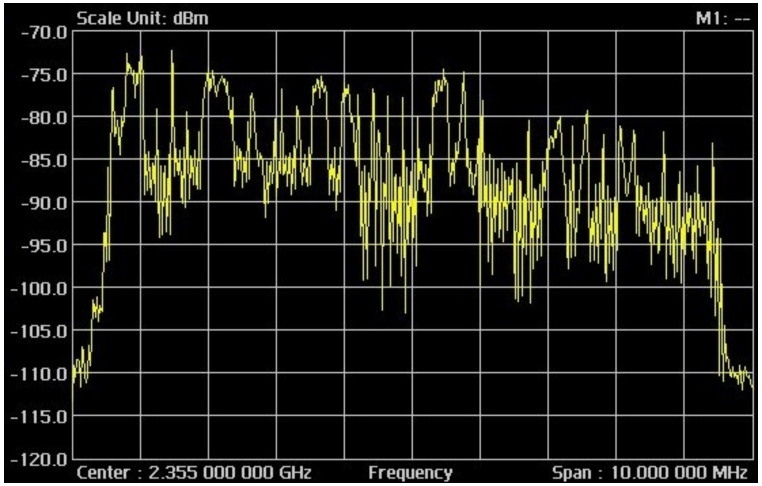
700 MHz Band 14 (10 MHz BW Ch.)



2100 MHz “AWS-3” Band 66 (20 MHz BW Ch.)



1900 MHz “PCS” Band 14 (20 MHz BW Ch.)



2300 MHz “WCS” Band (10 MHz BW Ch.)

3. Comparison between LTE and LMR

P25 SU (Radio Subscriber unit)

- simplex/half-duplex
- 2 to 5 watts RF Output
- optimized for low BW voice
- limited internal "intelligence"*
- limited production
- niche market (when compared to CE market)
- partially reliant upon network control
- Synthetic speech VOCODER (AMBE/IMBE)

LTE UE (User Equipment)

- full duplex or half-duplex
- 150~200mw (+23 dBm)* FirstNet +31dBm (1.25w)
- optimized for high speed data
- high internal "intelligence*"
- mass produced
- consumer market
- highly reliant upon network control
- AMR-W VOCODER (not just voice grade)

Here's something novel to consider…(you already know this but haven't thought about it)

A radio user can (when enabled) control:

- Your transmit power
- Your transmitted frequency
- Your transmitted bandwidth
- Your band of operation
- Your vocoder (half-full rate) via selected mode

LTE user (by design) has no control over:

- Your transmit power
- Your transmitted frequency
- Your transmitted bandwidth
- Your band of operation
- Your vocoder coding rate

3. Comparison between LTE and LMR

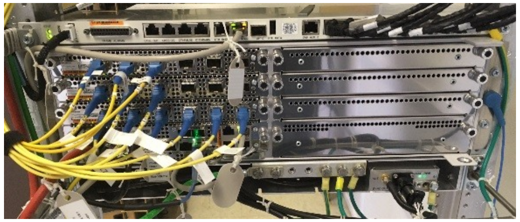
P25 LMR

- Typically analog & digital modulation
- UL & DL may use different modulation
- 50~100 watt transmitter output level
- User validation (ex. CTCSS/NAC) built-in
- Process 1 NB channel each

E Node B or "baseband unit"

- Digital modulation only (multi-order)
- Not really a BS…needs a remote radio head RRH
- Communicates with **I/Q Data** to RRH (yes…SDR)
- RRH usually +25 ~ +46 dBm (300 mw ~32w) Tx Pwr.
- Processes hundreds of subcarriers per channel

eNodeB

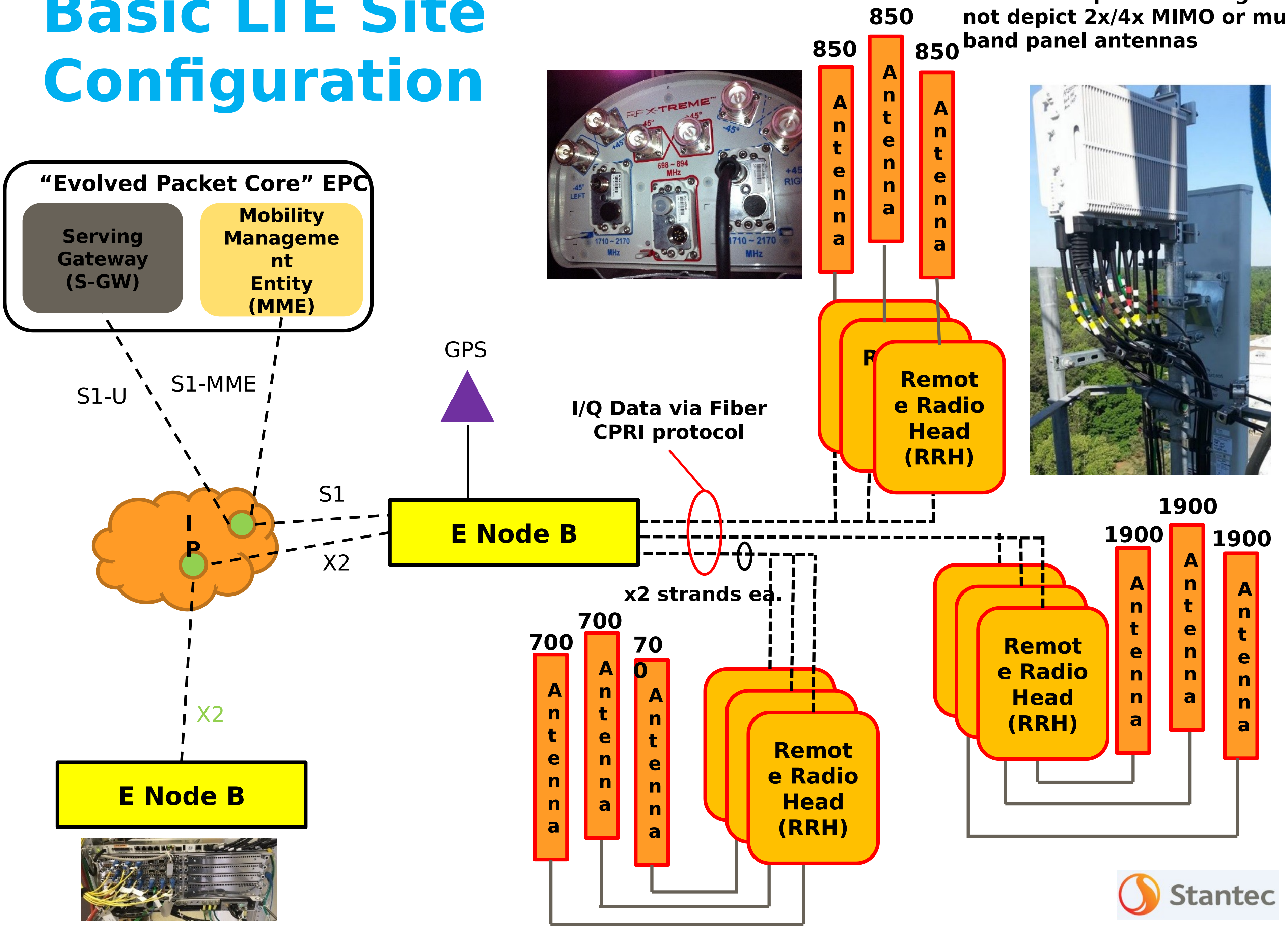


3. Comparison between LTE and LMR

Examples of outdoor mounted RRHs at macro sit

Basic LTE Site Configuration

Basic conceptual drawing – d
not depict 2x/4x MIMO or mul
band panel antennas



4. Implications for PS Communications

LTE Broadband Data Capability Empowers First Responders

LTE / FirstNet® offers ability for responders to more effectively communicate, interoperate, and manage response scenarios, examples include:

Streaming Video - active shooter
- hostage negotiations
- incident management
- dash cams
- transit coaches
- patient assessment
- helicopter downlink

High-Speed Data - biometrics
- Telemedicine (EMS sPatient Care Reporting)
- real time position & tracking
- location based asset management
- file transfer & database access

Voice - voice over LTE "VoLTE
- Mission critical PTT "MCPTT"
- interoperability with existing LMR systems via media serve
- future Proximity Service "ProSe" for direct mode off-netwo

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4. Implications for PS Communications

AT&T & FirstNet™ will provide (when contractual milestones are complete):

Dedicated, reliable, hardened, secure, regional/national high speed data network

Additional means (PTT over cellular) to access, monitor, and communicate on their home, native PS radio system, home or abroad (although unlikely in all rural or undeveloped areas)

The FirstNet-centric Market will provide:

Robust and evolving PS centric **device Apps** for voice, data, multimedia

- App stores for Public Safety
- driven by market demand and PS user feedback
- affordable prices driven by market competition (hopefully)

Diverse portfolio of User Equipment (smart devices)

Data Telemetry Devices (biometrics)

Low cost UE choices driven by market demand, vendor competition, and *mass pro*

LTE Vehicular Routers

4. Implications for PS Communications

AT&T & FirstNet™ First Responders will have:

- very economical Voice & Data Plans on AT&T (including families)
- highest QoS & Priority Access to the Network
- reserved use of Band 14 (if needed*)
- PTT over cellular capability
- preemption of non FirstNet users (if needed*)
- very high reserved broadband data speeds
- location based services
- *deployable resources* as needed

FIRSTNET READY

Tablet/Computer

B14 LTE Router

4. Implications for PS Communications

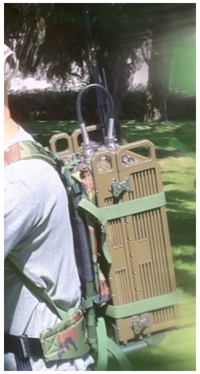
"Deployables"….what? Yep

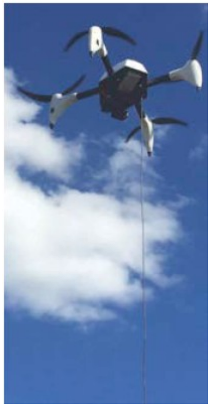
FirstNet and AT&T realize their national *coverage is not contiguous*
Rural areas *may lack coverage*
Urban areas (especially during an incident or disaster) *may lack capacity*
In-building coverage and capacity may need enhancement
Cell sites may not have gensets or *adequate standby power*

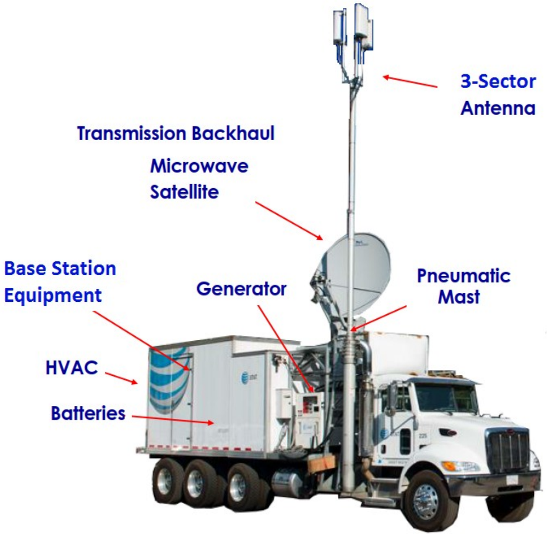
You may be thinking
…Cascadia event…
"this doesn't sound PS grade to me"
…it's all perspective

Solution…bring coverage, capacity, and power to the user
Deployable LTE solutions…think "Farm Animals"

COW - Cell Site on Wheels **COLT** – Cell Site on Light Truck **CROW** – Cell Repeater on Wheels
SOW - System in Wheels **GOAT** – Generator on Trailer System **EMU** – Emergency Manpack Unit







4. Implications for PS Communications?

Future Industry Trends to Observe:

Manufacturers Develop:

- Band 14 capable “smart” user devices

- LMR to LTE interoperability solutions

- Software Apps for smart devices for PS use

- Mission-Critical PTT (MCPTT) voice services

- Location Based Technologies & Apps

- tactical “deployable” field coverage enhancement assets

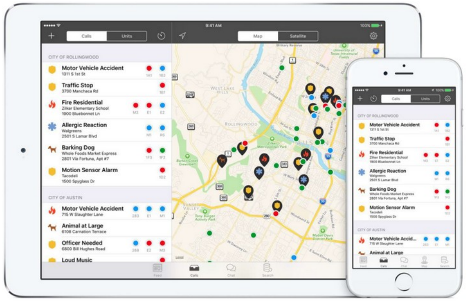
Strategic Partnerships & Mer

- LMR & Smart Device (cellphone) Manufacturers*

JVC Kenwood & Sonim
Motorola & Kodiak

- LMR & PTT over Cellular (POC) Techn

- PSAP/Dispatch Manufacturers & App



5. The Future

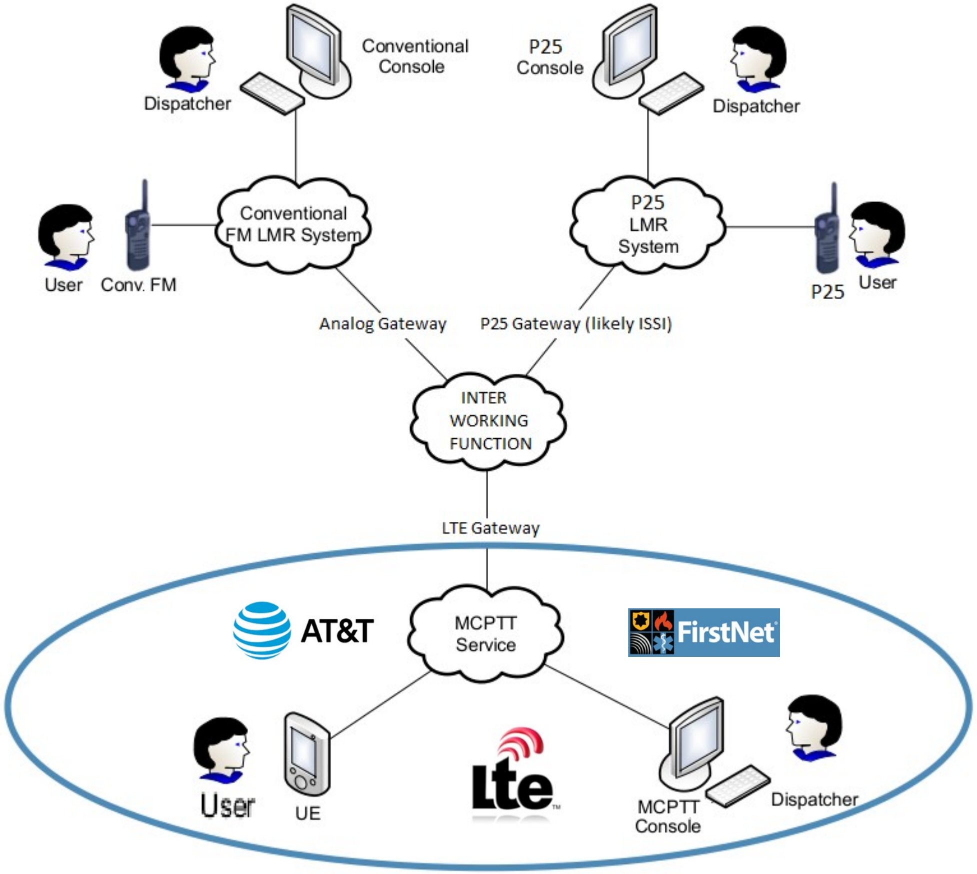
The Big Question many are asking…is this the end of LMR?

For now, absolutely not…let’s think about this for a second…

Was trunking the end of conventional radio? No
Was digital voice the end of analog voice? No
Was SSB the end of AM? No
Was AX.25 or PSK31 the end of RTTY or CW? No
Was emissions cheating the end of Volkswagen? No

The future LMR landscape *will loo*

- LTE and LMR systems will start to be merg
- LTE devices and P25 radios will be interop
- dispatching will support both radio and LTI



5. The Future

Nostradamus foretold that ….

- Rural regions will continue to utilize PTT LMR (analog & digital) for a long time
- Metro regions continue operating trunked systems with purpose-designed coverage, resilience, and interoperability
- Most governments will increase leveraging broadband data (AT&T, VZW, etc.)
- LMR & LTE "hybrid" transceivers (devices) will evolve and become de facto standard
- Future LTE handsets will become less distinguishable from LMR radios (and vice versa)
- Hybrid Radio Systems will evolve leveraging P25 and LTE interoperable communications (transparent to users)

In 15~20 years from now….?

We will be living in a very mature 5G technology world (likely 6G or 7G)

Many TV and FM off-air broadcast stations will be gone (Multimedia BCST)
Amateur Part 97 Spectrum may be much less than it is today

Mt Rainier won't be snow covered any more

Four Hams will meet for coffee, five opinions will form, and all will still be looking for a sub-$100 radio

The future of PS wireless technology, IMHO, will likely be most influenced by:

- ***The insatiable desire for more data***
- ***The bean counters***
- ***The ability of LMR manufacturers to e***

Questions?

THANK YOU!

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